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13. ABSTRACT *(Maximum 200 words)*
The objective of this proposal was to develop and apply computer-based, digital image processing techniques to the measurement of high-resolution (millimeter to decimeter) seafloor topography. Stereophotographs were collected as part of the 1990-1991 STRESS (Sediment TRansport Events of Shelves and Slopes) field program. A free-vehicle stereocamera tripod was deployed in mid-November 1990 at the 90-m STRESS site and successfully recovered in mid-March 1991. Results of the automatic image fusion research were disappointing, hence STRESS stereophotographs were analyzed manually using an analytical stereocomparator. During the deployment, five qualitatively different bed configurations were observed. In order of decreasing frequency these were: (1) biogenically reworked bed, (2) smoothed to scoured bed, (3) current-rippled bed, (4) scour-pitted bed, and (5) wave-rippled beds. Total vertical bed relief within the field of view was found to be typically less than 6 cm and the r-m-s vertical relief was of order 1 cm. Maximal relief occurred when the bed was current rippled (heights average 2 cm and lengths are about 15 cm) and was minimal following scour events. This study demonstrated that seafloor relief can change rapidly over short time scales.

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ENHANCED IMAGING TECHNIQUES FOR THE STUDY OF THE TIME-EVOLUTION OF MICROSCALE BED GEOMETRY

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Introduction and Rationale

The objective of this proposal was to develop and apply computer-based, digital image processing techniques to the measurement of high-resolution (millimeter to decimeter) seafloor topography. Specifically, it was hoped that the mean elevation and variance (i.e., roughness) of the seabed could be measured on horizontal and vertical scales of millimeters. Temporal variation in these two aspects of the sediment surface are important because: (1) local variations in the horizontal and vertical scales of roughness affect the structure of the near-bed flow field and the spatial distribution of bottom stress, and (2) absolute sediment erosion and/or deposition provide the ultimate record of the stress history at that location. In addition, following prolonged periods of excess shear stress, various bed configurations (e.g., current ripples or flute marks) are produced that reflect the nature of the near-bed flow and levels of suspended sediment. A prerequisite to understanding these various processes and products, is the collection and thorough analysis of field data on the time-evolution of microscale bed geometry.

Using funding provided by a WHOI postdoctoral fellowship and a subcontract from the University of Washington, stereophotographs were collected as part of the 1990-1991 STRESS (Sediment TRansport Events of Shelves and Slopes) field program. A free-vehicle stereocamera tripod was deployed in mid-November 1990 at the 90-m STRESS site and successfully recovered in mid-March 1991. Stereophotographs of a 40 by 60 cm area of the seafloor were taken at 12 hour intervals for approximately 90 days. These stereophotographs revealed a wide diversity of bed configurations and apparent roughnesses that suggested further analysis would be fruitful. An intrinsic problem with manual stereophotogrammetry is its labor-intensiveness. To manually measure an image that is 40 by 60 cm at a horizontal resolution of a millimeter, requires roughly 240,000 separate floating point measurements. This would take a skilled photogrammetrist over 100 full days, and that would only be one image! Clearly computer-based methods were worth investigating.

Automatic image fusion is typically based on the optimization of cross-correlations of local pixel domains between the right and left images. This is done by either making assumptions about the surface geometry (e.g., that it varies smoothly) or by using image segmentation algorithms to search for edges or lines in the photographs and compute their parallax. Regardless of which optimization method is used, images are first digitized and then geometrically rectified to correct for lens aberrations and nonplanarity between the two film planes of the stereocamera. In the case of the STRESS photographs, which contain a precisely machined Roseau plate (cross hairs), geometric corrections are likely to be relatively straightforward. Because Wheatcroft had little prior experience with image fusion algorithms, a collaborator was sought. The person identified for the work was Dr. Howard Schultz (Department of Computer Science, University of Massachusetts, Amherst), and he was funded through a subcontract.

Accomplishments and Results

Results of the automatic image fusion research were disappointing. Shultz's algorithm was based on the fact that if the left and right images could be resampled into an epipolar coordinate

system, then the vertical component of the disparity vanishes everywhere. As a result, the time required to compute the disparity map is greatly reduced, and the accuracy of the map is increased. For the STRESS images the system stereobase-to-height ratio is small (~0.1). This constraint on vertical resolution was known, and was to have been compensated for by a small pixel splitting factor, which is a measure (in pixels) of the accuracy that two objects can be aligned. Relatively large areas of uniform brightness on the mud bottom meant that the pixel splitting factor was unexpectedly large, hence it was not possible to resolve high frequency height information using Shultz's algorithm. Low-frequency (e.g., horizontal spacings of a few cm, vertical resolution of ~0.5 cm) height information could be extracted digitally. Automatic image fusion of underwater images is attainable, but further work will be required.

The STRESS stereophotographs were analyzed manually using an analytical stereocomparator. During the 90-d deployment, five qualitatively different bed configurations were observed (Wheatcroft, 1991; 1994). In order of decreasing frequency these were: (1) biogenically reworked bed, (2) smoothed to scoured bed, (3) current-rippled bed, (4) scour-pitted bed, and (5) wave-rippled beds. Flow directions for the physical bed configurations were approximately parallel to the local isobaths, with the current ripples always indicative of poleward flow to the NW, whereas the scour-pitted bed was always indicative of equatorward flow to the SE. Flow directions of the smoothed to scoured bed were variable. A preliminary explanation, that is consistent with Ekman layer dynamics and local observations, is that NW flow produces downwelling conditions which advect sediment laden water from the inner portion of the mid-shelf mud belt, (i.e., inshore of the stereocamera) thus producing depositional bedforms. When flow is to the SE, the situation is reversed (i.e., upwelling advects relatively clear water past the stereocamera) and bed forms are erosional (Wheatcroft, 1994).

Total vertical bed relief within the field of view was found to be typically less than 6 cm and the r-m-s vertical relief was of order 1 cm. Maximal relief occurred when the bed was current rippled (heights average 2 cm and lengths are about 15 cm) and was minimal following scour events. Biological reworking visually destroys the physical bed forms in 1-2 days, but low frequency relief, which manifests itself in the height variance, persists for much longer. Because the recurrence interval of bottom erosion at the 90-m STRESS site is of order 1 week during the winter, biological reworking apparently does not return the bed to a pre-storm equilibrium condition as is probably the case in deep-water environments (e.g., HEBBLE).

References

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